Directly Driven, Tamped Heavy Ion Fusion Targets

Matthew Terry
Lawrence Livermore National Laboratory

19th International Symposium on Heavy Ion Fusion

Berkeley, CA

August 13, 2012

The Heavy Ion Fusion Science Virtual National Laboratory

LLNL-PRES-573832

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Security, LLC, Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, by LBNL under Contract DE-AC02-05CH11231, and by PPPL under Contract DE-AC02-76CH03073.

Outline

Target Performance
Ion beam requirements

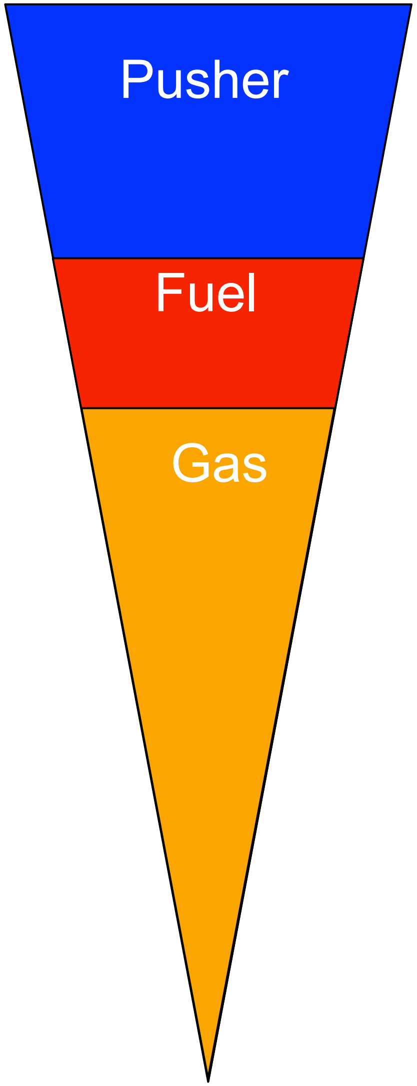
Unique target physics
- Bragg & Tamper Shocks
- Combined pusher and radiation drive

Hydrodynamic Stability

Conclusions and Further work

Tamped targets evolved from simple direct drive targets

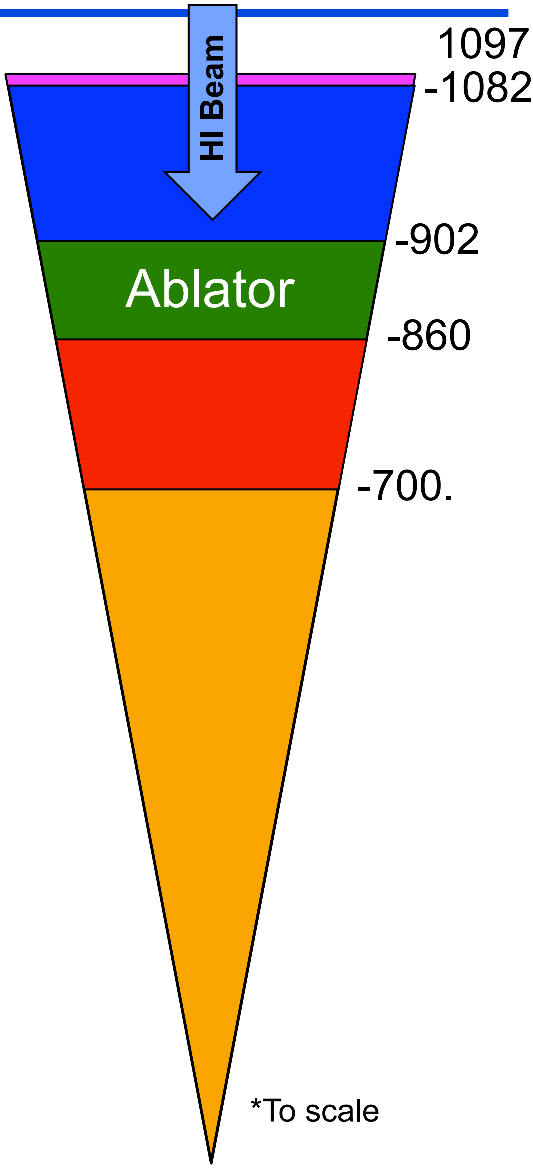
- Beam kinetic energy increases in time to follow ablation front
- Accelerator requirements for this target are very demanding
  - Low kinetic energy beams are difficult to focus
  - Total power required huge number of beam lines
  - Change in beam kinetic energy is large



Target design uses both exploding pusher and x-ray driven ablation to drive implosion

- Fuel compression (t < breakout) driven by expanding CH pusher
- Shell acceleration (t > breakout) driven by x-ray ablation of Si-doped plastic
- Target has yield of 27 MJ @ 435 kJ driver energy

Material	**Thickness (μm)**	**Density (g/cm^3)**
Rhodium	20	12.41
CH	164	1.049
CH + 1% Si	100	1.0735
DT Ice	160	0.245
DT Gas	700	3.e-4



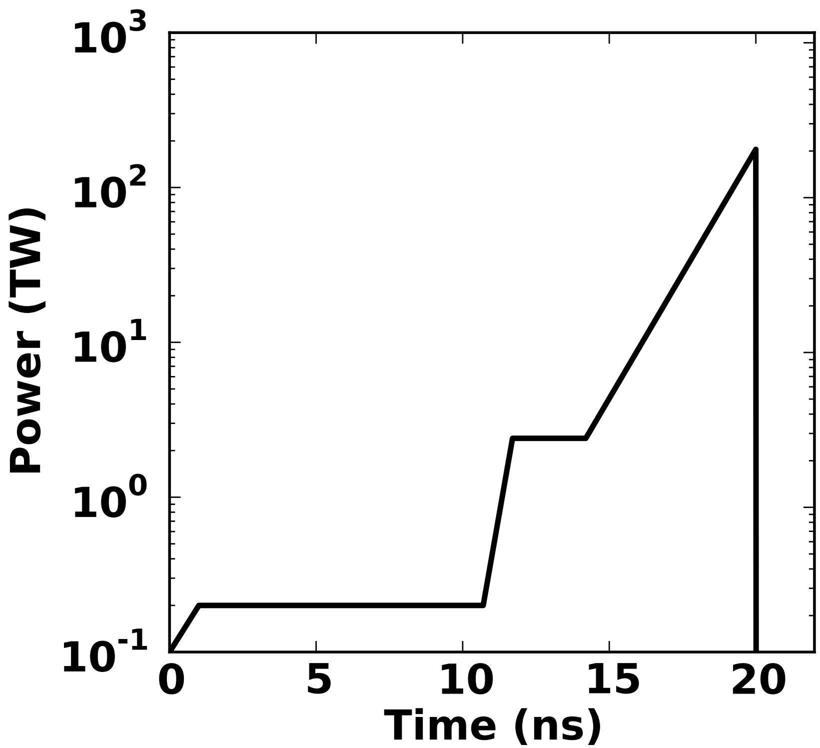
Target Performance

- Hydra simulations show efficient coupling leading to high gain at low driver energy
- Moderately low adiabat despite crude pulse shaping
- Large convergence ratio
- Hot-spot ignition physics is NIF-like

Aspect Ratio	4.88
Implosion Velocity	360 km/s
Adiabat	1.65
ρR_{DT}	1.8
CR	35
Yield	26 MJ
Gain	63
Burnup	24%
T_{rad}	350 eV
η_{hydro}	4.7 %

Ion pulse requirements are modest, but require novel pulse shape

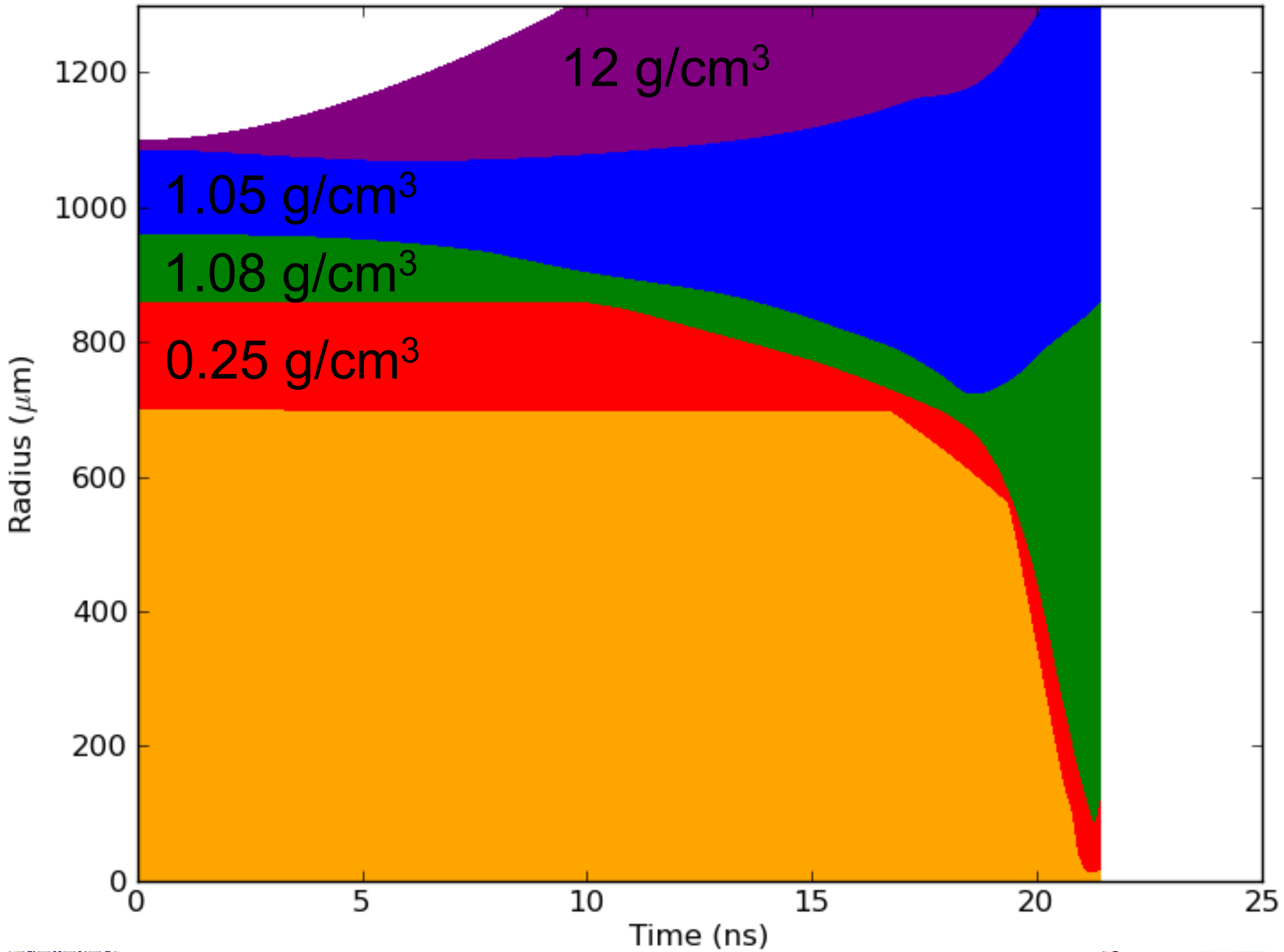
- 2 pedestals + linear ramp power profile
  - Constant kinetic energy
- Slope of ramp controls the handoff from pusher drive to ablation drive



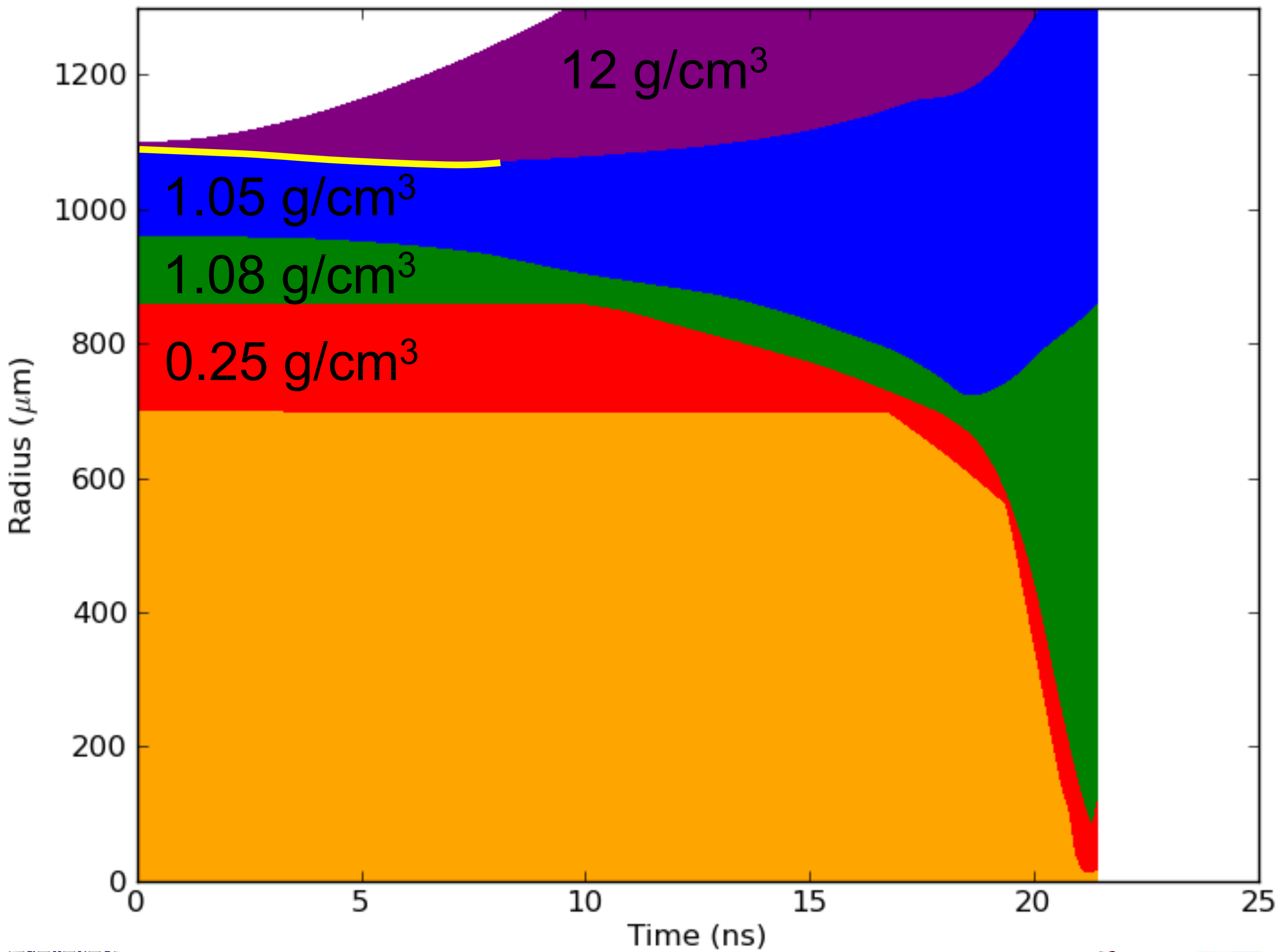
Pulse length	21 ns
Total energy	435 kJ
Peak power*	150 TW
Kinetic Energy	4.6 GeV
Ion Species	Pb^+
Spot Size (Gaussian FWHM)	1 mm
Total Charge*	97 μC
Peak Current*	33 kA
Perveance limited number of beams	11

*Total for all beams

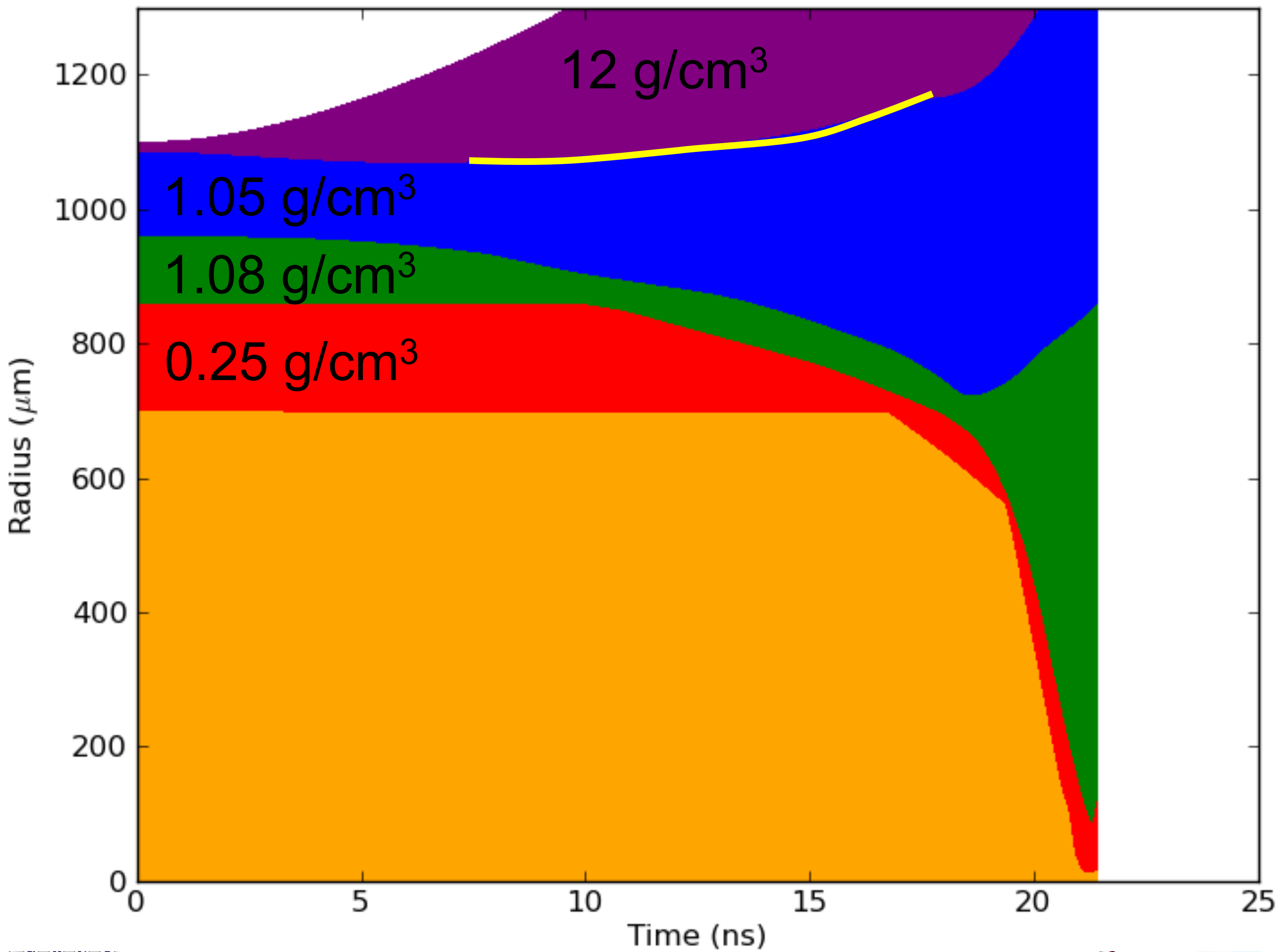
Shell linear stability



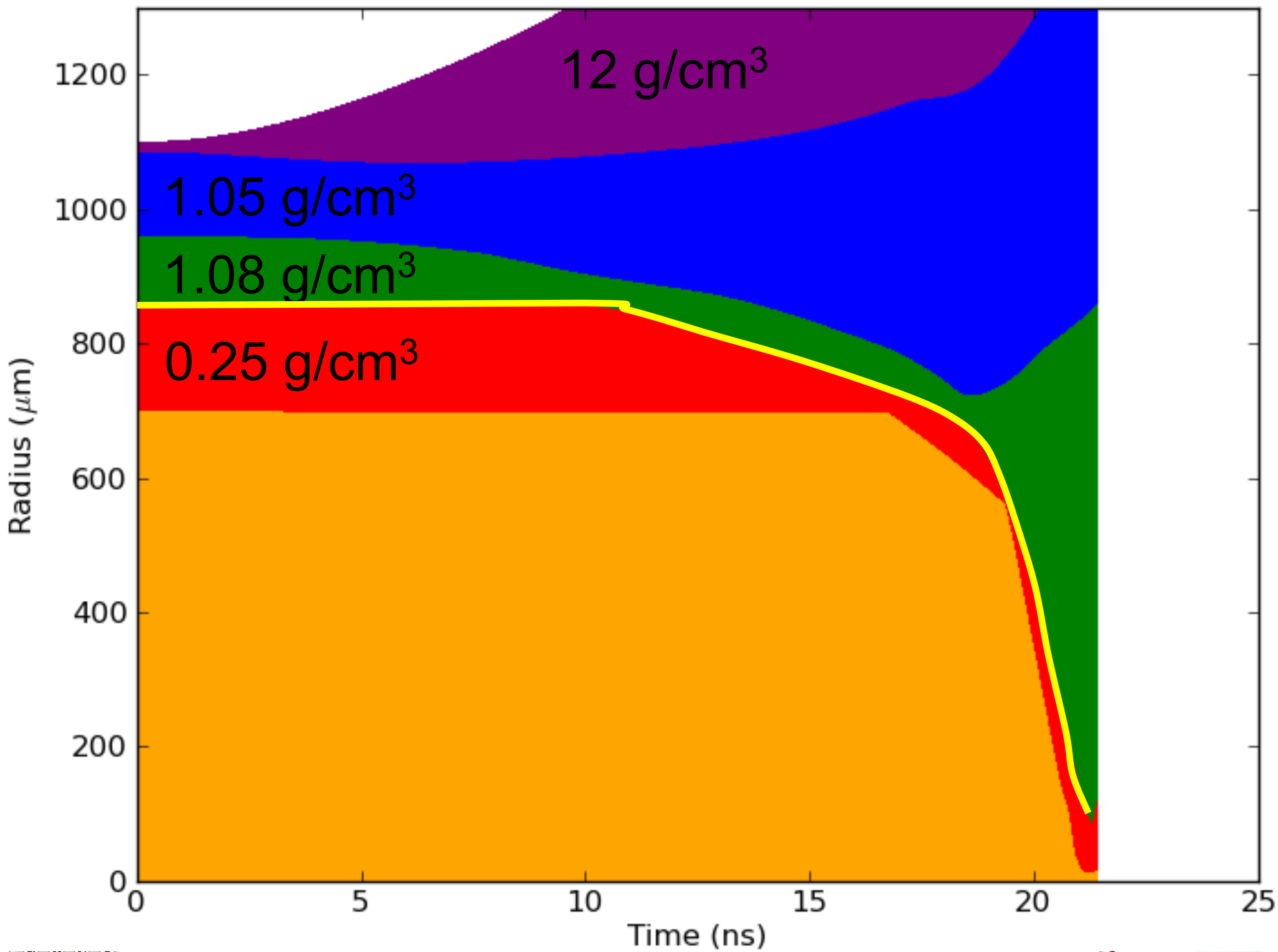
Early time Tamper-Pusher interface is stable



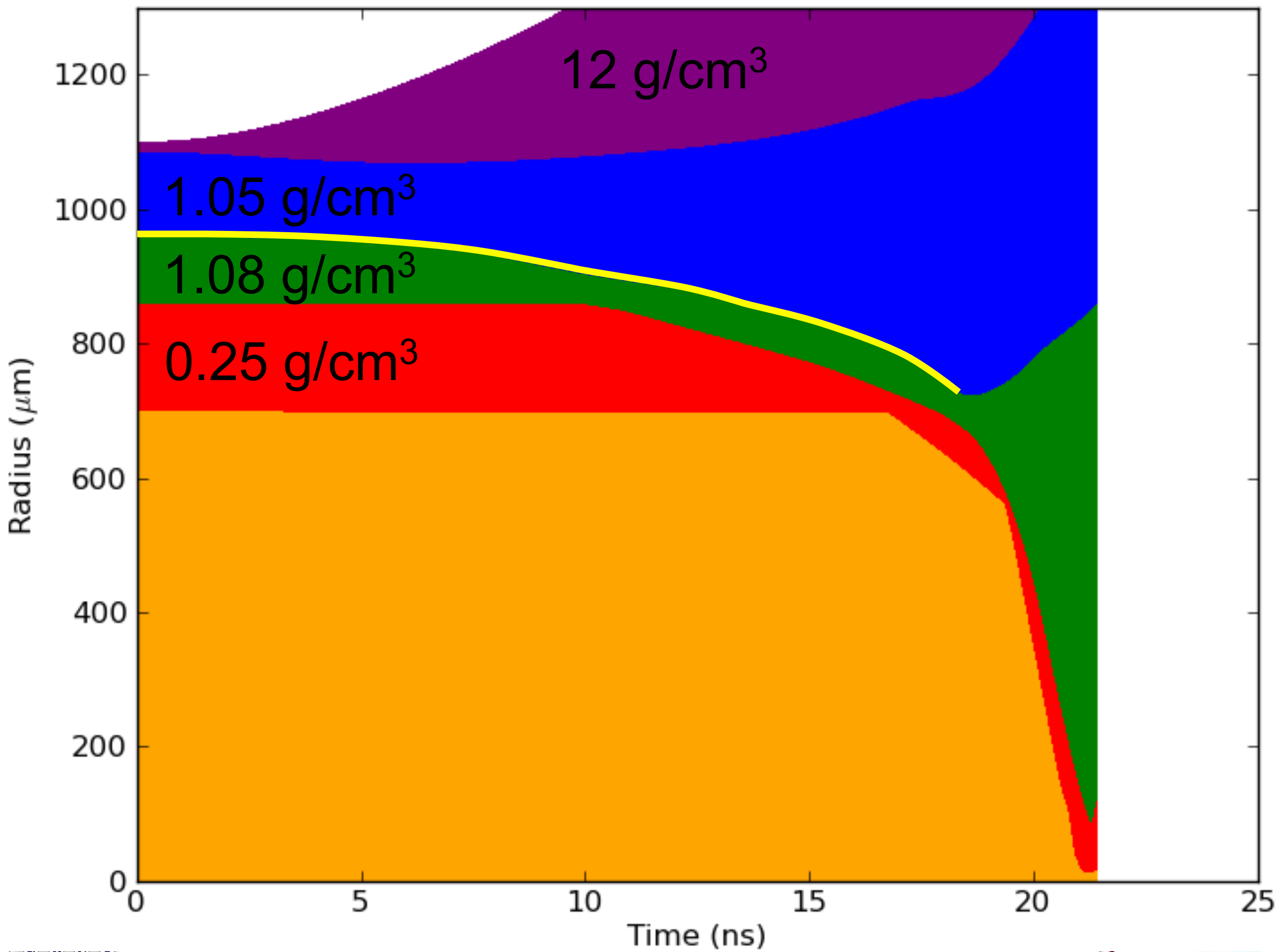
Interface goes RT-unstable, but tamper has weak hydrodynamic coupling at this point



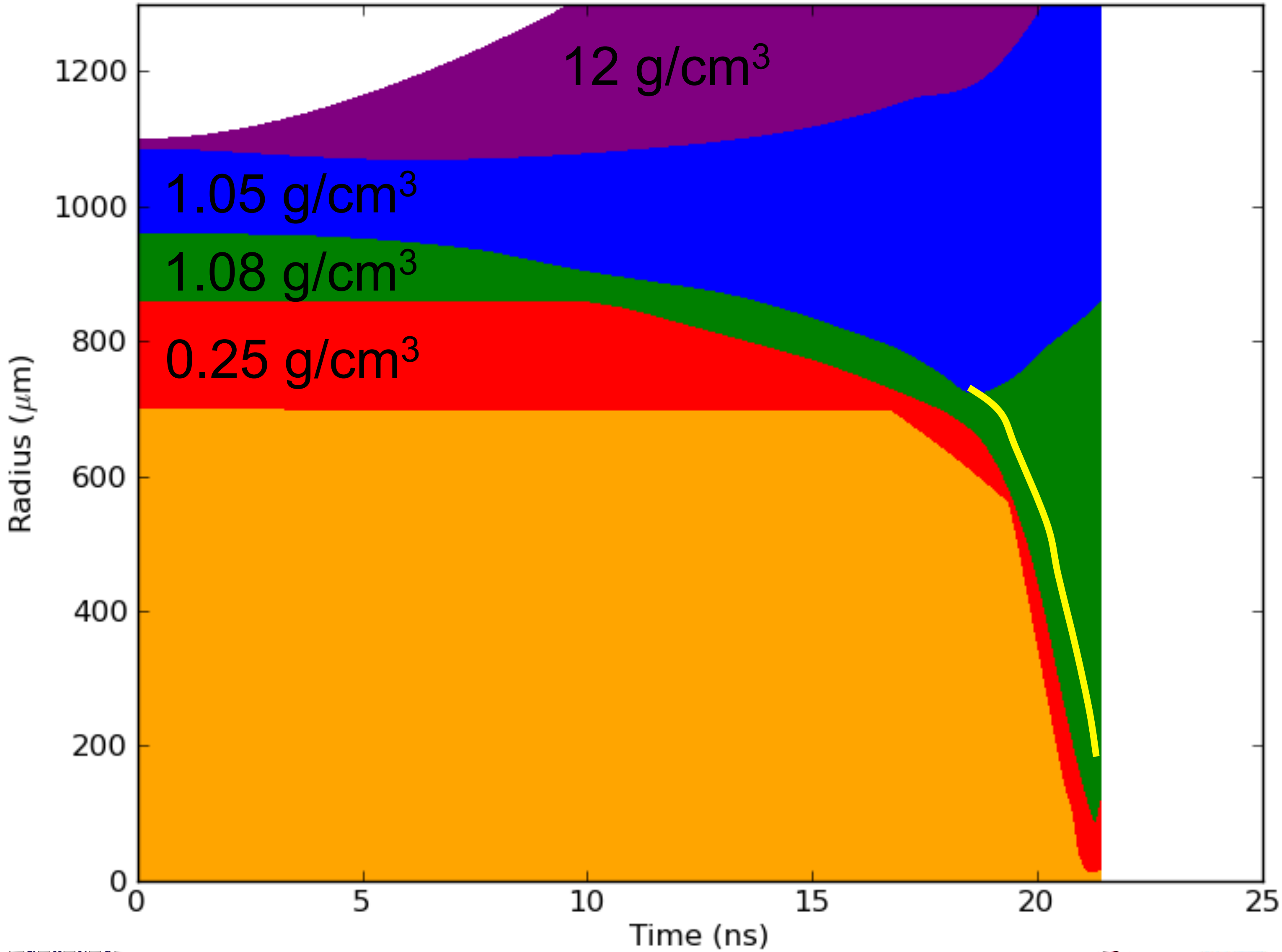
Ablator-Fuel interface is stable during shell acceleration



Pusher-Ablator interface weakly unstable, but under weak acceleration.

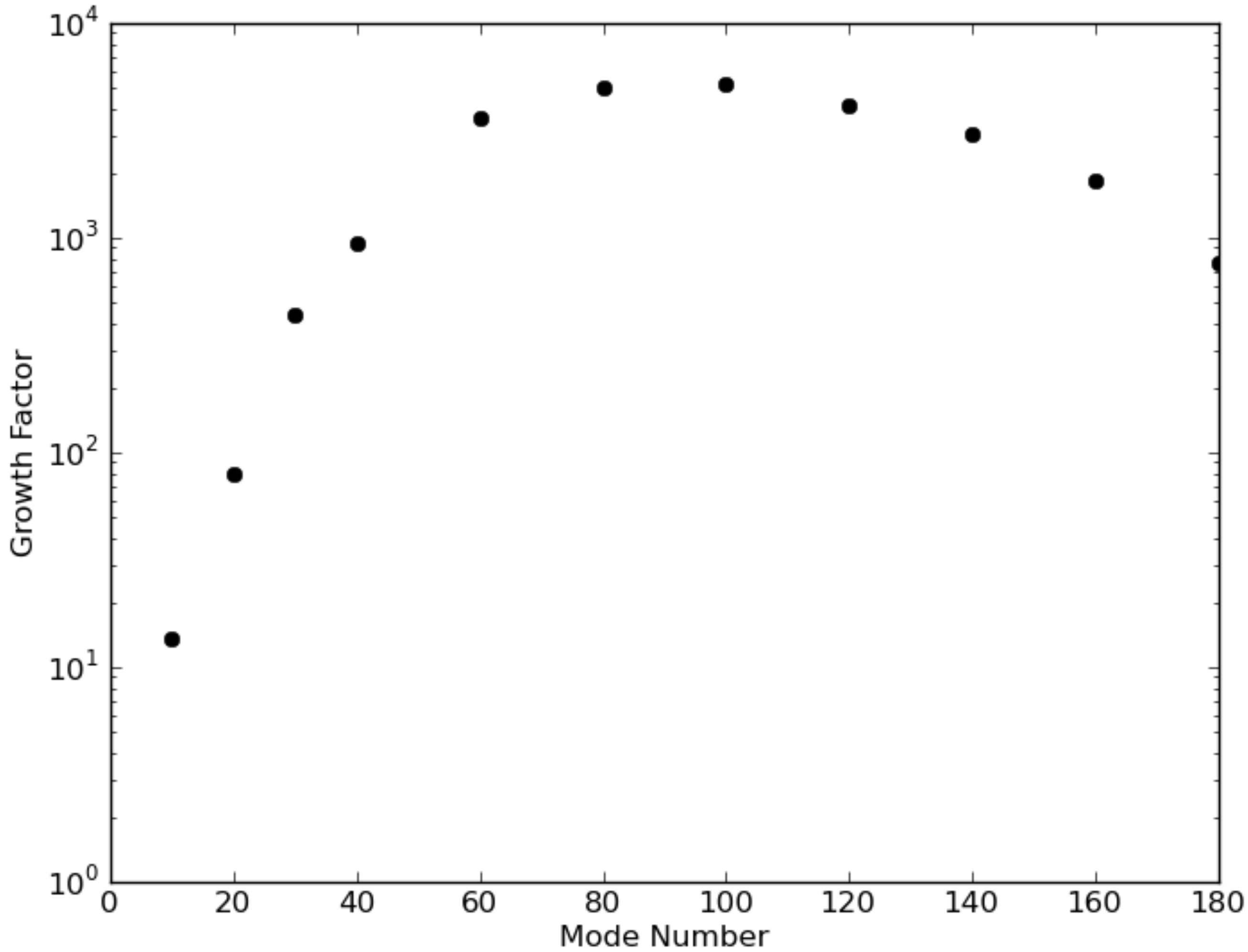


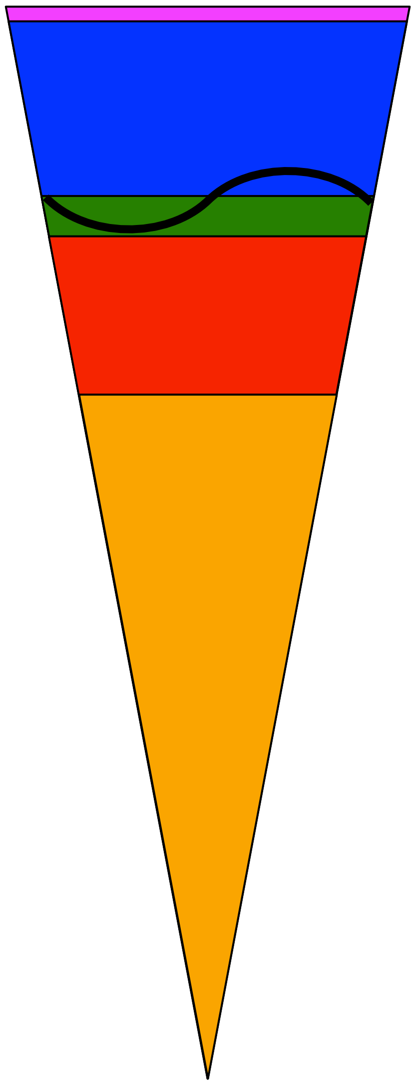
Shell remains RT unstable, but now experiences radiative stabilization



Single-mode growth factors at ablator interface peak ~5200

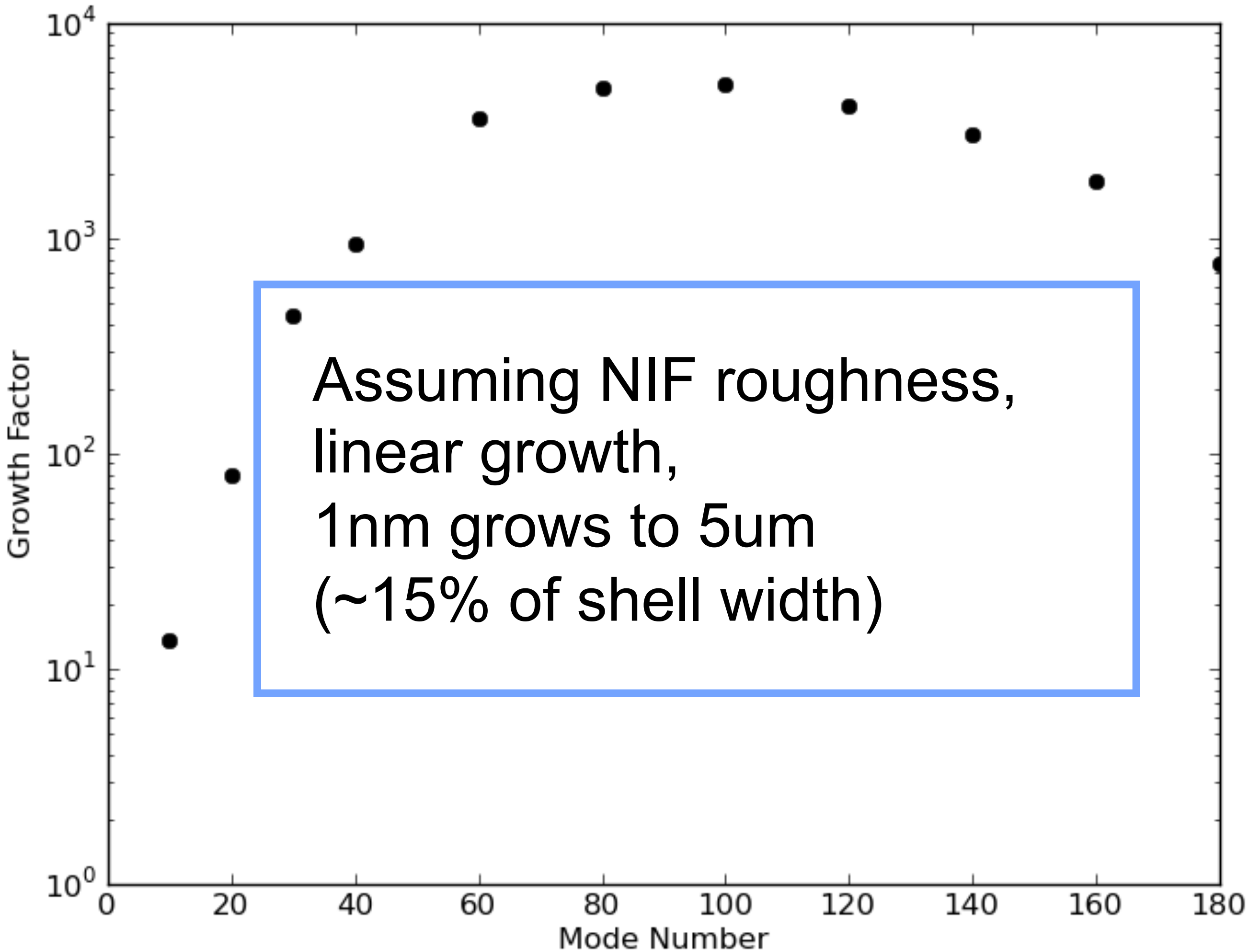
- There is text here



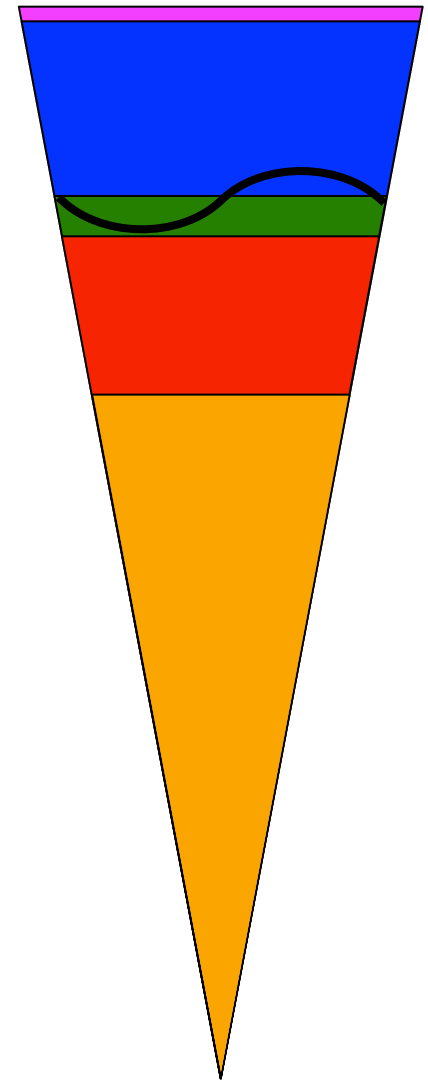


Single-mode growth factors at ablator interface peak ~5200

- There is text here



Assuming NIF roughness,
linear growth,
1nm grows to 5um
(~15% of shell width)



Conclusions and potential future direction

- Tamped targets show high gain at low beam energy
- Beam parameters look attractive

- Large growth factors put demanding tolerances on uniformity
  - Mitigated through greater offset between beam terminus & ablator?

- High density (~2 g/cm^3) pushers for better stability?
- Single pusher/ablator material?